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MAP PROJECTIONS FOR USE WITH THE GEOGRAPHIC INFORMATION SYSTEM

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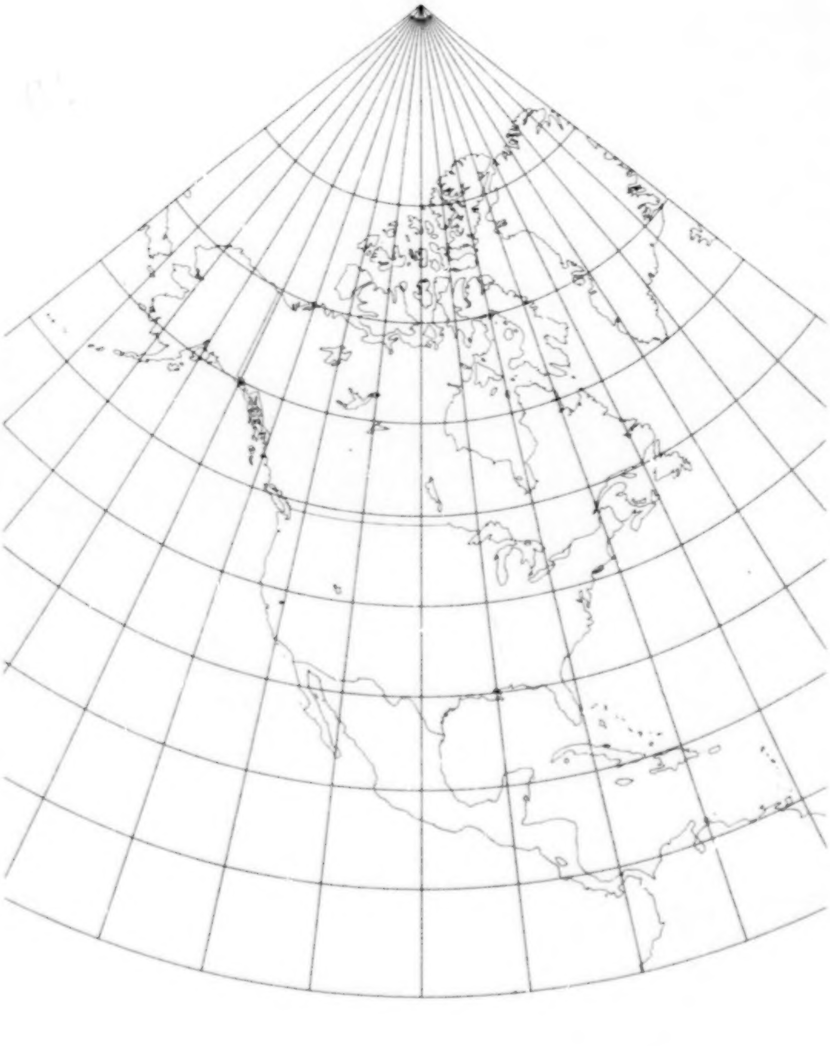

Fish and Wildlife Service

U.S. Department of the Interior

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FWS/OBS-84/17
July 1984

MAP PROJECTIONS FOR USE WITH THE GEOGRAPHIC INFORMATION SYSTEM

by

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PREFACE

This document has been prepared to assist users of the Geographic Information System (GIS), originally developed at the Western Energy and Land Use Team (WELUT), in understanding and using the various map projections which are available. Currently, 20 map projections may be used in the GIS. The map projections software is a modification of the General Cartographic Transformation Package obtained from the U.S. Geological Survey (USGS). Users who are unfamiliar with the GIS should contact the Rapid Assessment Methods (RAM) Group at the address below for information.

Users who have been trained in the component software systems of the GIS [MOSS (Map Overlay and Statistical System), COS (Cartographic Output System), and AMS (Analytical Mapping System)], and who have some introduction to principles of cartography, will find this document most helpful. Users who desire a more technical and mathematical treatment of map projections are referred to Snyder (1982) where tables of constants and formulae for specific projections may be found. This manual is not intended for the general audience but rather is a specific document designed to assist the software user and technician in answering software prompts and in understanding the reason for their responses.

Choice of the map projection to be used, and appropriate definition values to be entered, are variable for a given map and study area. Although this document provides some direction to these questions, no definitive answers are possible. Thus, no examples of sample input have been provided. Users unsure of the desired projection or its definition should consult a cartographer or contact the address below for assistance. In general, for small study areas the map projection used is irrelevant and noticeable differences are only apparent in larger maps, for example State or Country maps.

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CONTENTS

Page

DISCLAIMER ii
PREFACE iii
FIGURES vi
TABLES vii
ACKNOWLEDGEMENTS viii

INTRODUCTION 1
THE MAP PROJECTION MENU 5
THE ELLIPSOID MENU 10
OPTION 0 GEOGRAPHIC (LAT/LON) 12
OPTION 1 UNIVERSAL TRANSVERSE MERCATOR 14
OPTION 2 STATE PLANE 17
OPTION 3 ALBERS CONICAL EQUAL AREA 23
OPTION 4 LAMBERT CONFORMAL CONIC 26
OPTION 5 MERCATOR 29
OPTION 6 POLAR STEREOGRAPHIC 31
OPTION 7 POLYCONIC 33
OPTION 8 EQUIDISTANT CONIC A & B 35
OPTION 9 TRANSVERSE MERCATOR 37
OPTION 10 STEREOGRAPHIC 39
OPTION 11 LAMBERT AZIMUTHAL EQUAL AREA 41
OPTION 12 AZIMUTHAL EQUIDISTANT 43
OPTION 13 GNOMONIC 45
OPTION 14 ORTHOGRAPHIC 46
OPTION 15 VERTICAL NEAR SIDE PERSPECTIVE 49
OPTION 16 SINUSOIDAL 50
OPTION 17 EQUIRECTANGULAR (PLATE CARREE) 51
OPTION 18 MILLER CYLINDRICAL 52
OPTION 19 VAN DER GRINTEN I 54
OPTION 20 OBLIQUE MERCATOR (HOTINE) A & B 56

GLOSSARY 58
SELECTED REFERENCES 60

FIGURES

Number — Page

1 Projection of the global surface onto the three major developable surfaces 2

2 The graticule of meridians and parallels on the global surface 13

3 Zones of the Universal Transverse Mercator Grid in the United States 15

4 Zones of the State Plane coordinate system 18

5 Albers Equal Area Conic projection 24

6 Lambert Conformal Conic projection 27

7 Mercator projection 30

8 Polar Stereographic projection and its geometric construction 32

9 Polyconic projection of North America 34

10 Stereographic projection 40

11 Lambert Azimuthal Equal Area projection 42

12 Polar aspect of the Azimuthal Equidistant projection 44

13 Orthographic projection 47

14 Miller Cylindrical projection 53

15 Van der Grinten projection 55

TABLES

Number		Page
1	Construction, major property, and primary use of map projections	6
2	Parameters required for definition of map projections	8
3	Universal Transverse Mercator zones, central meridians, and longitude ranges	16
4	State Plane coordinate system zone numbers, projection types, and zone code numbers for the United States	19

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INTRODUCTION

A map projection is the manner in which the spherical surface of the earth is represented on a two-dimensional surface. This can be accomplished by direct geometric projection or by a mathematically derived transformation. There are many kinds of projections, but all involve transfer of the distinctive global patterns of parallels of latitude and meridians of longitude onto an easily flattened, or developable, surface. The three most common developable surfaces are the cylinder, cone, and plane (Fig. 1). A plane is already flat, while a cylinder or cone may be cut and laid out flat, without stretching. Thus, map projections may be classified into three general families, cylindrical, conical, and planar or azimuthal.

Regardless of what type of projection is used, it is inevitable that some error or distortion will occur in transforming a spherical surface into a flat surface. Ideally, a distortion-free map has four valuable properties; conformality, equivalence, equidistance, and true direction. However, no map projection can be true in all properties. Therefore, it is devised to be true in selected properties, or most often, a compromise among selected properties. Map properties are an additional basis for map projection classification.

Conformality is the characteristic of true shape, wherein a projection preserves the shape of any small geographical area. This is accomplished by exact transformation of angles around points. One necessary condition is the perpendicular intersection of grid lines as on the globe. The property of conformality is important in maps which are used for analyzing, guiding, or recording motion, as in navigation.

Equivalence is the characteristic of equal area. Areas on one portion of a map are in scale with areas in any other portion. Preservation of equivalence involves inexact transformation of angles around points and thus, is mutually exclusive with conformality except along one or two selected lines. The property of equivalence is important in maps which are used for comparing density and distribution data, as in populations.

Equidistance is the characteristic of true distance measuring. The scale of distance is constant over the entire map. This property can be fulfilled on any given map from one, or at most two, points in any direction or along certain lines. Equidistance is important in maps which are used for analyzing velocity, for example, ocean currents. Typically, reference lines such as the equator or a meridian are chosen to have equidistance and are termed standard parallels or standard meridians.

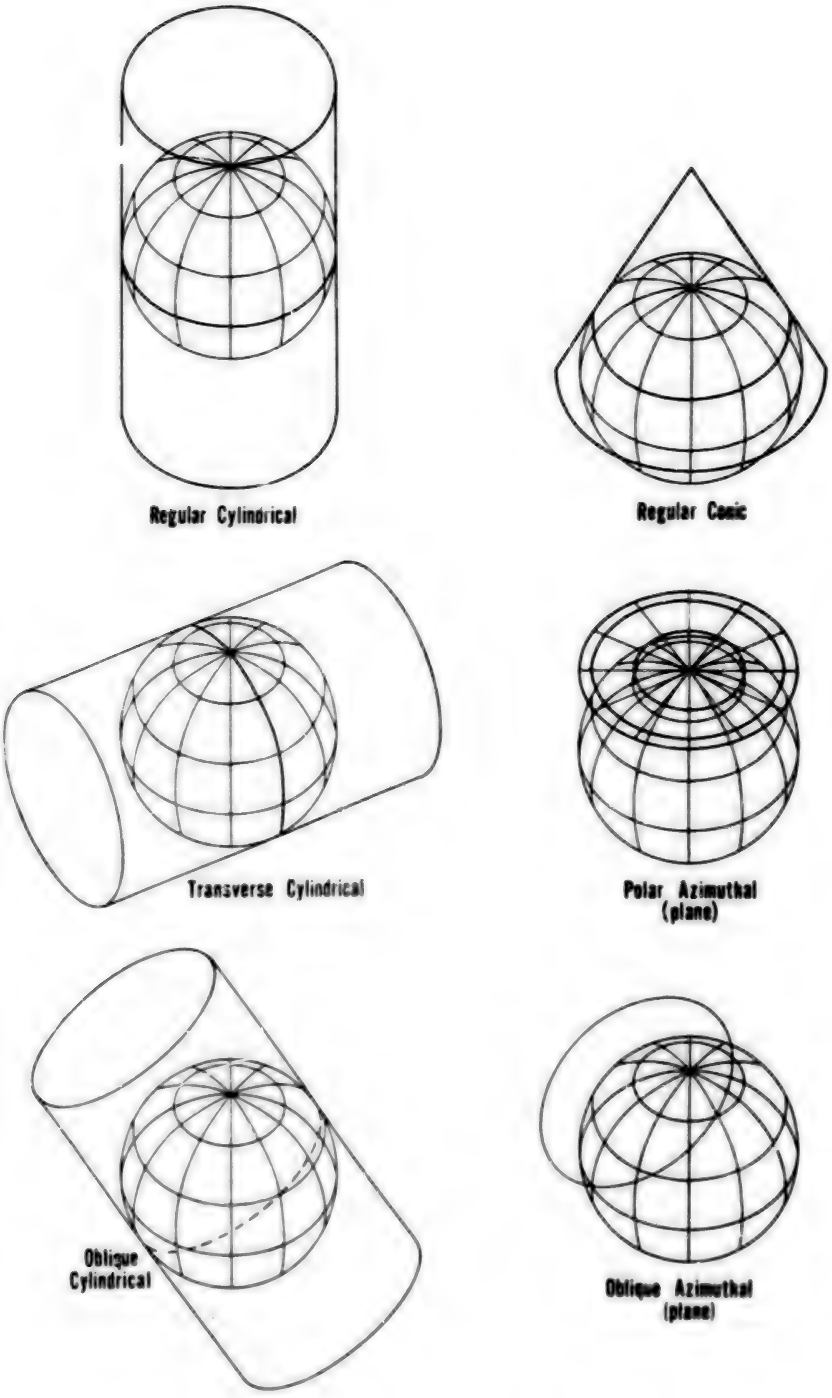


Figure 1. Projection of the global surface onto the three major developable surfaces (from Snyder 1982).

True direction is characterized by a direction line between two points which crosses reference lines, for example, meridians, at a constant angle or azimuth. These are termed rhumb lines and this property makes it comparatively easy to chart a navigational course. However, on a spherical surface, the shortest surface distance between two points is a great circle along which azimuths constantly change. Thus, a more desirable property may be where certain great circles are represented by straight lines. This characteristic is most important in aviation. Note that all meridians are great circles, but the only parallel that is a great circle is the equator.

Planar, or azimuthal, projections are accomplished by drawing lines from a given perspective point through the globe onto a tangent plane. This is conceptually equivalent to tracing a shadow of a figure cast by a light source. A tangent plane intersects the global surface at only one point and is perpendicular to a line passing through the center of the sphere. Thus, these projections are symmetrical around a chosen center or central meridian. Choice of the projection center determines the aspect, or orientation, of the projection surface. Planar projections may be centered on the poles (polar aspect), at a point on the equator (equatorial aspect), or at any other orientation (oblique aspect). The origin of the projection lines, i.e., the perspective point, may also assume various positions. For example, it may be the center of the earth (gnomonic), an infinite distance away (orthographic), or on the earth's surface opposite the projection plane (stereographic).

Conical projections are accomplished by intersecting, or touching, a cone with the global surface and mathematically projecting lines onto this developable surface. A tangent cone intersects the global surface to form a circle. This is conceptually equivalent to the touching of a sweatband of a hat on a head. On this line of intersection, termed the standard parallel, the map will be relatively error-free and possess equidistance. Cones may also be secant, and intersect the global surface forming two circles which will possess equidistance. Note that use of the word "secant", in this instance, is only conceptual, not geometrically accurate. As with planar projections, the conical aspect may be polar, equatorial, or oblique.

Cylindrical projections are accomplished by intersecting, or touching, a cylinder with the global surface. The surface is mathematically projected onto the cylinder which is then "cut" and "unrolled". A tangent cylinder will intersect the global surface on only one line to form a circle as with a tangent cone. This central line of the projection is commonly the equator and will possess equidistance. If the cylinder is rotated 90 degrees from the vertical, i.e., the long axis becomes horizontal, the aspect becomes transverse and the central line of the projection becomes a chosen standard meridian. A secant cylinder, one slightly less in diameter than the globe, will have two lines possessing equidistance. Perhaps the most famous cylindrical projection is the Mercator, which became the standard navigational map, possessing true direction and conformality.

Although a great number of projections have been devised, the majority of them are geometric or mathematical variants of the basic direct geometric projection families described previously. Choice of the projection to be used will depend upon the true property or combination of properties desired for effective cartographic analysis.

The previous discussion of direct geometric projections assumes that the earth is a sphere, and for many maps this is satisfactory. However, due to rotation of the earth around its axis, the planet bulges slightly at the equator. This flattening of the sphere makes it an oblate spheroid which is an ellipse rotated around its shorter axis. An ellipse is defined by its semimajor (long) and semiminor (short) axes. The amount of flattening of the earth is expressed as the ratio $f = (a-b)/a$ where a is the equatorial radius (semimajor axis) and b is the polar radius (semiminor axis). Most map projections use eccentricity (e^2) rather than flattening. The relationship is $e^2 = 2f-f^2$. The flattening of the earth is about 1 part in 300 and becomes significant in map accuracy at a scale of 1:100,000 or larger. Formulas and tables of constants for both the sphere and ellipsoid are available in Snyder (1982). In North America the ellipsoid in use is the Clarke 1866, named after the British geodesist A.R. Clarke. Other ellipsoids are used in different parts of the world.

Map projections require a point of reference on the earth's surface. Most often this is the center, or origin, of the projection. This point is defined in two coordinate systems; spherical or geographical (lat,lon; see option 0 below) and rectangular (x,y). With spherical coordinates the origin of the projection is defined by latitude and by longitude of a central meridian. Latitude and longitude are defined with respect to an origin located at the intersection of the equator and the prime (Greenwich) meridian. With rectangular coordinates the origin of the projection is defined by values of false easting and false northing. These values are defined with respect to an origin (0,0) typically located south and west of the origin of the projection, i.e., a "false" origin (thus "false" easting and northing). In practice, this eliminates negative rectangular coordinate values and allows locations on a map projection to be defined by positive coordinate pairs. Values of false easting are read first and may be in meters or feet.

Additional sources of information concerning cartography, coordinate systems, maps, and map projections are included in the list of selected references.

THE MAP PROJECTION MENU

When using the GIS, and its component systems, MOSS, COS, and AMS, it may be desirable to employ a specific map projection or to change from one type of projection to another. Certain commands, prompts, and responses (specific to each particular component system) will cause the following map projection menu to appear:

```
                         MAP PROJECTION MENU

 0 GEOGRAPHIC(LAT/LON)
 1 UNIVERSAL TRANSVERSE MERCATOR      11 LAMBERT AZIMUTHAL EQUAL AREA
 2 STATE PLANE                        12 AZIMUTHAL EQUIDISTANT
 3 ALBERS CONICAL EQUAL AREA          13 GNOMONIC
 4 LAMBERT CONFORMAL CONIC            14 ORTHOGRAPHIC
 5 MERCATOR                           15 VERTICAL NEAR SIDE PERSPECTIVE
 6 POLAR STEREOGRAPHIC                16 SINUSOIDAL
 7 POLYCONIC                          17 EQUIRECTANGULAR(PLATE CARREE)
 8 EQUIDISTANT CONIC A & B            18 MILLER CYLINDRICAL
 9 TRANSVERSE MERCATOR                19 VAN DER GRINTEN I
10 STEREOGRAPHIC                      20 OBLIQUE MERCATOR (HOTINE)

PROJECTION (0-20)?
```

Choice of the projection to be used will depend upon the desired major property and the region to be mapped (Table 1). After choosing the desired map projection, several parameters are required for its definition (Table 2). These parameters fall into three general classes; definition of the spheroid, definition of the surface viewing window, and definition of scale. Each required parameter is presented as a prompt, except definition of the spheroid which is defined by a menu option. A brief description of the map projections and ellipsoids available and an explanation of the definition prompts follows. In responding to prompts it is important to use the same units of measure throughout. Note also that values for longitude west of Greenwich, England and values for latitude south of the equator are to be entered as negatives.

Table 1. Construction, major property, and primary use of map projections.

Map projection		Construction	Property	Use
0	Geographic	N/A[a]	N/A	Data entry, spherical coordinates
1	Universal Transverse Mercator	Cylinder (see #9)	Conformal	Data entry, plane coordinates
2	State Plane	(see #4, #9)	Conformal	Data entry, plane coordinates
3	Alberts Conical Equal Area	Cone	Equivalent	Middle latitudes, E-W expanses
4	Lambert Conformal Conic	Cone	Conformal True Direction	Middle latitudes, E-W expanses, flight (straight great circles)
5	Mercator	Cylinder	Conformal True Direction	Non-polar regions, navigation (straight rhumb lines)
6	Polar Sterographic	Plane	Conformal	Polar regions
7	Polyconic	Cone	Compromise	N-S expanses
8	Equidistant Conic	Cone	Equidistant	Middle latitudes, E-W expanses
9	Transverse Mercator	Cylinder	Conformal	N-S expanses
10	Stereographic	Plane	Conformal	Hemispheres, continents
11	Lambert Azimuthal Equal Area	Plane	Equivalent	Square or round expanses
12	Azimuthal Equidistant	Plane	Equidistant	Polar regions, radio/seismic work (straight great circles)

Table 1. (concluded).

Map projection		Construction	Property	Use
13	Gnomonic	Plane	Compromise	Navigation, seismic work (straight great circles)
14	Orthographic	Plane	Compromise	Globes, pictorial
15	Vertical Near-Side Perspective	Plane	Compromise	Hemispheres or less
16	Sinusoidal	Pseudo-Cylinder	Equivalent	N-S expanses or equatorial regions
17	Equirectangular	Cylinder	Compromise	City maps, computer plotting (simplistic)
18	Miller Cylindrical	Cylinder	Compromise	World maps
19	Van der Grinten	N/A	Compromise	World maps
20	Oblique Mercator	Cylinder	Conformal	Oblique expanses (e.g., Hawaiian islands), satellite tracking

[a] Not applicable.

Table 2. Parameters required for definition of map projections.

Parameter	Projection type (#)[a]																	
	3	4	5	6	7	8[b]	9	10	11	12	13	14	15	16	17	18	19	20[b]
[Definition of spheroid]																		
ELLIPSOID SELECTION MENU	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
[Definition of surface viewing window]																		
FALSE EASTING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
FALSE NORTHING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LONGITUDE OF CENTRAL MERIDIAN	X	X	X		X	X	X							X	X	X	X	
LATITUDE OF ORIGIN OF PROJECTION	X	X			X	X	X											X
LONGITUDE OF CENTER OF PROJECTION								X	X	X	X	X	X					
LATITUDE OF CENTER OF PROJECTION								X	X	X	X	X	X					
LATITUDE OF FIRST STANDARD PARALLEL	X	X				X												
LATITUDE OF SECOND STANDARD PARALLEL	X	X				X												
LATITUDE OF TRUE SCALE			X	X														
LONGITUDE BELOW POLE				X														

Table 2. (concluded).

	Projection type (#)[a]																	
Parameter	3	4	5	6	7	8[b]	9	10	11	12	13	14	15	16	17	18	19	20[b]
[Definition of scale]																		
SCALE FACTOR AT CENTRAL MERIDIAN							X											
HEIGHT OF PERSPECTIVE POINT ABOVE SPHERE													X					
SCALE FACTOR AT CENTER OF PROJECTION																		X

---

[a] Parameters for definition of map projection types 0-2 are not applicable and are described in text.

[b] Additional parameters required for definition of the map projection are described in text.

THE ELLIPSOID MENU

Calculation of a map projection requires definition of the ellipsoid (or spheroid) in terms of axes lengths and eccentricity squared (or radius of the reference sphere). Several principal ellipsoids are in use by one or more countries. Differences are due primarily to calculation of the ellipsoid for a particular region of the earth's surface. Only recently have satellite tracking data provided ellipsoid determinations for the entire earth. However, these ellipsoids may not give the "best fit" for a particular region (Snyder 1982). In North America, the ellipsoid in use is the Clarke 1866. If other regions are to be mapped, different projections should be used. Upon choosing a desired projection type, the following menu of ellipsoid choices will appear:

```
                 ELLIPSOID MENU

0 CLARKE 1866 (default)        10 MODIFIED EVEREST
1 CLARKE 1880                  11 MODIFIED AIRY
2 BESSEL                       12 WALBECK
3 NEW INTERNATIONAL 1967       13 SOUTHEAST ASIA
4 INTERNATIONAL 1909           14 AUSTRALIAN NATIONAL
5 WGS 72                       15 KRASOVSKY
6 EVEREST                      16 HOUGH
7 WGS 66                       17 MERCURY 1960
8 GRS 1980                     18 MODIFIED MERCURY 1968
9 AIRY                         19 SPHERE OF RADIUS 6370977 M

ELLIPSOID (0-19)?
```

Principal use of these ellipsoids is as follows:

0 Clarke 1866 - North America and the Phillipines
1 Clarke 1880 - France and Africa
2 Bessel (1841) - Central Europe, Chile, and Indonesia
3 International 1909 (= Hayford) - remaining parts of the world not listed here
4 New International 1967 - as above, more recent calculation
5 WGS 72 (World Geodetic System 1972) - NASA (satellite)
6 Everest (1830) - India, Burma, and Pakistan
7 WGS 66 (World Geodetic System 1966) - as 5 above, older version
8 GRS 1980 (Geodetic Reference System) - expected to be adopted in North America for 1983 earth-centered coordinate system (satellite)

9 Airy (1949) - England
10 Modified Everest - as 6 above, more recent version
11 Modified Airy - as 9 above, more recent version
12 Walbeck (1819) - Soviet Union, up to 1910
13 Southeast Asia - as named
14 Australian National (1965) - Australia
15 Krasovsky (1940) - Soviet Union
16 Hough - as 3 above, with modification of ellipse axes
17 Mercury 1960 - early satellite, rarely used
18 Modified Mercury 1968 - as above, more recent calculation
19 Sphere of Radius 6370997 m - a perfect sphere with the same surface area as the Clarke 1866 ellipsoid

OPTION 0: GEOGRAPHIC (LAT/LON)

The geographic is a spherical coordinate system composed of parallels of latitude (lat) and meridians of longitude (lon; Fig. 2). Both divide the circumference of the earth into 360 degrees which are further subdivided into minutes and seconds (60 sec = 1 min, 60 min = 1 degree).

Because the earth spins on an axis between the north and south poles, this allows construction of concentric, parallel circles, with a reference line exactly at the north-south center, termed the equator. The series of circles north of the equator are termed north latitudes and run from 0 degrees latitude (the equator) to 90 degrees North latitude (the north pole), and similarly southwards. Position in an east-west direction is determined from lines of longitude. These lines are not parallel and converge at the poles. However, they intersect lines of latitude perpendicularly. Unlike the equator in the latitude system, there is no natural zero meridian. In 1884, it was finally agreed that the meridian of the Royal Observatory in Greenwich, England would be the prime meridian. Thus, the origin of the geographic coordinate system is the intersection of the equator and the prime meridian. Note that the 180 degree meridian is the International Date Line.

If you choose option 0, Geographic, from the map projection menu, no prompts will follow and no response is necessary. Note that in responding to prompts for other projections, values for longitude are negative west of Greenwich and values for latitude are negative south of the equator.

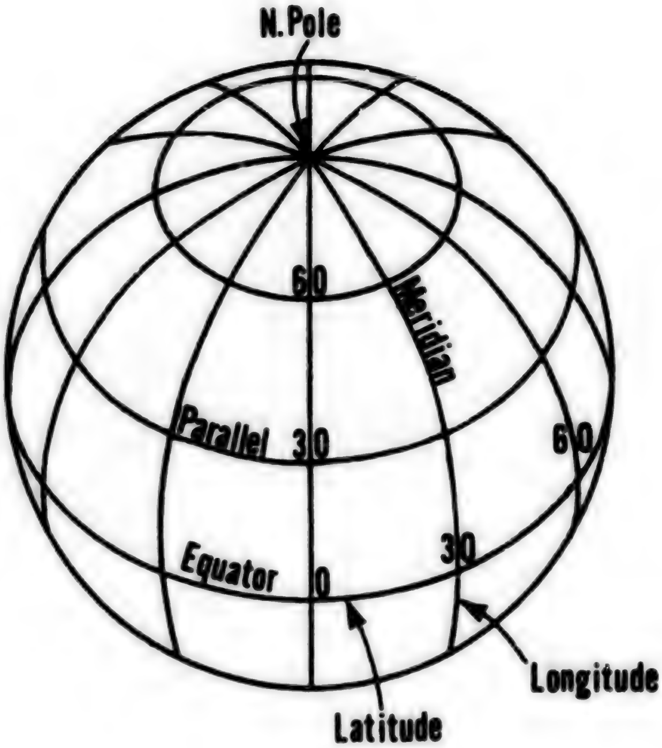


Figure 2. The graticule of meridians and parallels on the global surface (from Snyder 1982).

OPTION 1: UNIVERSAL TRANSVERSE MERCATOR

The Universal Transverse Mercator (UTM) is an international plane (rectangular) coordinate system developed by the U.S. Army which extends around the world from 84 degrees North to 80 degrees South. The world is divided into 60 zones each covering six degrees longitude. Each zone extends three degrees eastward and three degrees westward from its central meridian. Zones are numbered consecutively west to east from the 180 degree meridan (Fig. 3, Table 3). From 84 degrees North and 80 degrees South to the respective poles, the Universal Polar Stereographic (UPS) is used.

The Transverse Mercator projection (see option 9) is then applied to each UTM zone. Transverse Mercator is a transverse form of the Mercator cylindrical projection (see option 5). The projection cylinder is rotated 90 degrees from the vertical (polar) axis and can then be placed to intersect at a chosen central meridian. The UTM system specifies the central meridian of each zone. With a separate projection for each UTM zone, a high degree of accuracy is possible (one part in 1000 maximum distortion within each zone).

If the map to be projected extends beyond the border of the UTM zone, the entire map may be projected for any UTM zone specified by the user.

The following prompts appear if option 1, Universal Transverse Mercator, is chosen from the map projection menu. Respond to the prompts as described.

LONGITUDE OF ANY POINT WITHIN THE UTM ZONE ?

LATITUDE OF ANY POINT WITHIN UTM ZONE ?

Enter a longitude and latitude point somewhere within a UTM zone. The system will identify the actual UTM zone. Note that longitude values west of the prime meridian and latitude values south of the equator should be entered as negatives.

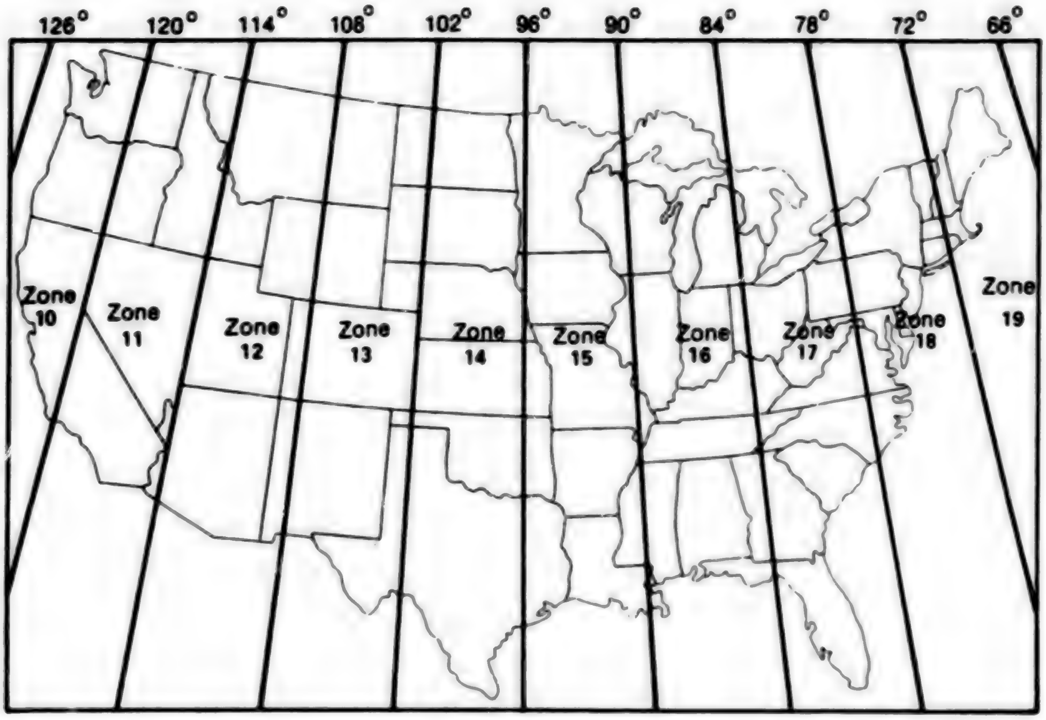


Figure 3. Zones of the Universal Transverse Mercator grid in the United States (from Muehrcke 1978).

Table 3. Universal Transverse Mercator zones, central meridians, and longitude ranges. All values are in full degrees east (E) or west (W) of the Greenwich prime meridian (0).

Zone	Central Meridian	Range	Zone	Central Meridian	Range
1	177W	180W-174W	31	3E	0 - 6E
2	171W	174W-168W	32	9E	6E- 12E
3	165W	168W-162W	33	15E	12E- 18E
4	159W	162W-156W	34	21E	18E- 24E
5	153W	156W-150W	35	27E	24E- 30E
6	147W	150W-144W	36	33E	30E- 36E
7	141W	144W-138W	37	39E	36E- 42E
8	135W	138W-132W	38	45E	42E- 48E
9	129W	132W-126W	39	51E	48E- 54E
10	123W	126W-120W	40	57E	54E- 60E
11	117W	120W-114W	41	63E	60E- 66E
12	111W	114W-108W	42	69E	66E- 72E
13	105W	108W-102W	43	75E	72E- 78E
14	99W	102W- 96W	44	81E	78E- 84E
15	93W	96W- 90W	45	87E	84E- 90E
16	87W	90W- 84W	46	93E	90E- 96E
17	81W	84W- 78W	47	99E	96E-102E
18	75W	78W- 72W	48	105E	102E-108E
19	69W	72W- 66W	49	111E	108E-114E
20	63W	66W- 60W	50	117E	114E-120E
21	57W	60W- 54W	51	123E	120E-126E
22	51W	54W- 48W	52	129E	126E-132E
23	45W	48W- 42W	53	135E	132E-138E
24	39W	42W- 36W	54	141E	138E-144E
25	33W	36W- 30W	55	147E	144E-150E
26	27W	30W- 24W	56	153E	150E-156E
27	21W	24W- 18W	57	159E	156E-162E
28	15W	18W- 12W	58	165E	162E-168E
29	9W	12W- 6W	59	171E	168E-174E
30	3W	6W- 0	60	177E	174E-180E

OPTION 2: STATE PLANE

The State Plane is an x,y coordinate system whose zones divide the U.S. into over 130 sections, each with its own projection surface and grid network (Fig. 4). With the exception of very narrow States such as Delaware, New Jersey, and New Hampshire, most States are divided into two to ten zones. The Lambert Conformal projection (see option 4) is used for zones extending mostly in an east-west direction. The Transverse Mercator projection is used for zones extending mostly in a north-south direction. Alaska, Florida, and New York use both Transverse Mercator and Lambert Conformal for different areas. The Aleutian panhandle of Alaska is prepared on the Oblique Mercator projection (see option 20).

Zone boundaries follow state and county lines, and, because each zone is small, distortion is less than one in 10,000. Each zone has a centrally located origin and a central meridian which passes through this origin. Two zone numbering systems are currently in use; the U.S. Geological Survey (USGS) code system and the National Ocean Service (NOS) code system (Table 4); but other numbering systems exist.

The following prompts will appear if option 2, State Plane, is selected from the map projection menu. Respond to the prompts as described.

```
UNITS MENU
 1 FEET
 2 METERS
?

STATE PLANE ZONE(3101-6426) ?
```

Identify the units desired for easting and northing (feet or meters) and the State Plane zone.

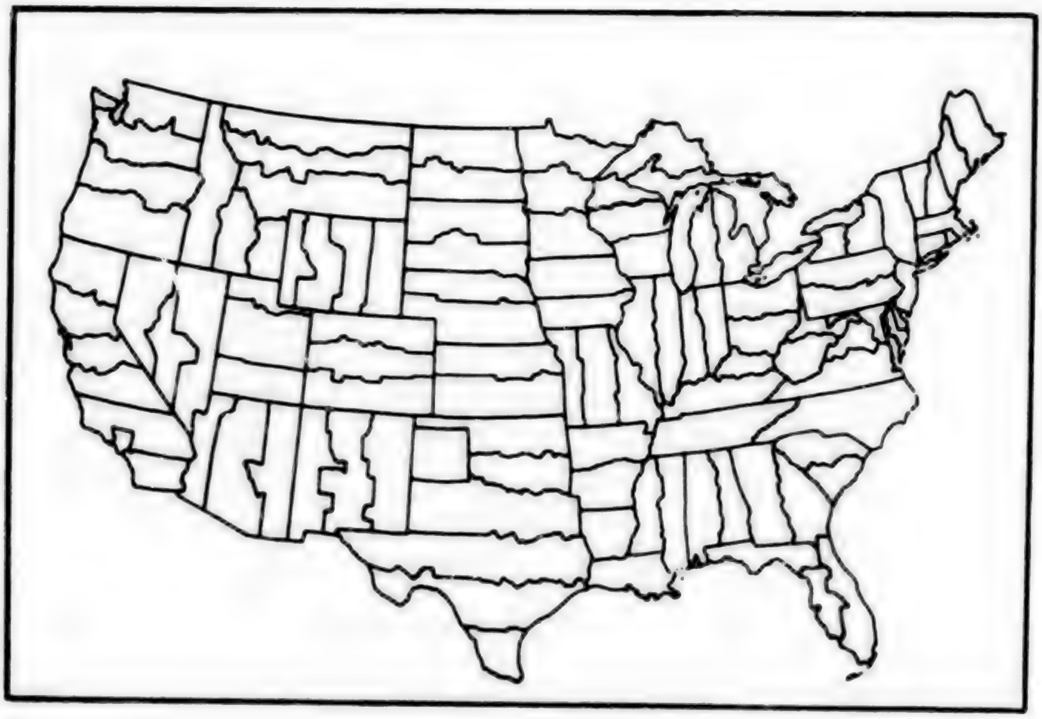


Figure 4. Zones of the State Plane coordinate system (from Muehrcke 1978).

Table 4. State Plane coordinate system zone numbers, projection types, and zone code numbers for the United States. (Tr Merc = Transverse Mercator, Lambert = Lambert Conformal Conic, and Oblique = Hotine Oblique Mercator) (Adapted from Snyder 1982).

			Code Number	
State	Zone Name	Type	USGS	NOS
Alabama	East	Tr Merc	3101	-101
	West	Tr Merc	3126	-102
Alaska	1	Oblique	6101	-5001
	2	Tr Merc	6126	-5002
	3	Tr Merc	6151	-5003
	4	Tr Merc	6176	-5004
	5	Tr Merc	6201	-5005
	6	Tr Merc	6226	-5006
	7	Tr Merc	6251	-5007
	8	Tr Merc	6276	-5008
	9	Tr Merc	6301	-5009
	10	Lambert	6326	-5010
American Samoa	-------	Lambert	----	-----
Arizona	East	Tr Merc	3151	-201
	Central	Tr Merc	3176	-202
	West	Tr Merc	3201	-203
Arkansas	North	Lambert	3226	-301
	South	Lambert	3251	-302
California	I	Lambert	3276	-401
	II	Lambert	3301	-402
	III	Lambert	3326	-403
	IV	Lambert	3351	-404
	V	Lambert	3376	-405
	VI	Lambert	3401	-406
	VII	Lambert	3426	-407
Colorado	North	Lambert	3451	-501
	Central	Lambert	3476	-502
	South	Lambert	3501	-503
Connecticut	-------	Lambert	3526	-600
Delaware	-------	Tr Merc	3551	-700
District of Columbia	Use Maryland or Virginia North			
Florida	East	Tr Merc	3601	-901
	West	Tr Merc	3626	-902
	North	Lambert	3576	-903
Georgia	East	Tr Merc	3651	-1001
	West	Tr Merc	3676	-1002

Table 4. (continued).

			Code Number	
State	Zone Name	Type	USGS	NOS
Guam	-------	Special	----	-----
Hawaii	1	Tr Merc	5876	-5101
	2	Tr Merc	5901	-5102
	3	Tr Merc	5926	-5103
	4	Tr Merc	5951	-5104
	5	Tr Merc	5976	-5105
Idaho	East	Tr Merc	3701	-1101
	Central	Tr Merc	3726	-1102
	West	Tr Merc	3751	-1103
Illinois	East	Tr Merc	3776	-1201
	West	Tr Merc	3801	-1202
Indiana	East	Tr Merc	3826	-1301
	West	Tr Merc	3851	-1302
Iowa	North	Lambert	3876	-1401
	South	Lambert	3901	-1402
Kansas	North	Lambert	3926	-1501
	South	Lambert	3951	-1502
Kentucky	North	Lambert	3976	-1601
	South	Lambert	4001	-1602
Louisiana	North	Lambert	4026	-1701
	South	Lambert	4051	-1702
	Offshore	Lambert	6426	-1703
Maine	East	Tr Merc	4076	-1801
	West	Tr Merc	4101	-1802
Maryland	-------	Lambert	4126	-1900
Massachusetts	Mainland	Lambert	4151	-2001
	Island	Lambert	4176	-2002
Michigan (Tr Merc)	East	Tr Merc	4201	-2101
	Central	Tr Merc	4226	-2102
	West	Tr Merc	4251	-2103
(Lambert)	North	Lambert	6351	-2111
	Central	Lambert	6376	-2112
	South	Lambert	6401	-2113
Minnesota	North	Lambert	4276	-2201
	Central	Lambert	4301	-2202
	South	Lambert	4326	-2203
Mississippi	East	Tr Merc	4351	-2301
	West	Tr Merc	4376	-2302
Missouri	East	Tr Merc	4401	-2401
	Central	Tr Merc	4426	-2402
	West	Tr Merc	4451	-2403
Montana	North	Lambert	4476	-2501
	Central	Lambert	4501	-2502
	South	Lambert	4526	-2503

Table 4. (continued).

State	Zone Name	Type	Code Number USGS	NOS
Nebraska	North	Lambert	4551	-2601
	South	Lambert	4576	-2602
Nevada	East	Tr Merc	4601	-2701
	Central	Tr Merc	4626	-2702
	West	Tr Merc	4651	-2703
New Hampshire	-------	Tr Merc	4676	-2800
New Jersey	-------	Tr Merc	4701	-2900
New Mexico	East	Tr Merc	4726	-3001
	Central	Tr Merc	4751	-3002
	West	Tr Merc	4776	-3003
New York	East	Tr Merc	4801	-3101
	Central	Tr Merc	4826	-3102
	West	Tr Merc	4851	-3103
	Long Island	Lambert	4876	-3104
North Carolina	-------	Lambert	4901	-3200
North Dakota	North	Lambert	4926	-3301
	South	Lambert	4951	-3302
Ohio	North	Lambert	4976	-3401
	South	Lambert	5001	-3402
Oklahoma	North	Lambert	5026	-3501
	South	Lambert	5051	-3502
Oregon	North	Lambert	5076	-3601
	South	Lambert	5101	-3602
Pennsylvania	North	Lambert	5126	-3701
	South	Lambert	5151	-3702
Rhode Island	-------	Tr Merc	5176	-3800
South Carolina	North	Lambert	5201	-3901
	South	Lambert	5226	-3902
South Dakota	North	Lambert	5251	-4001
	South	Lambert	5276	-4002
Tennessee	-------	Lambert	5301	-4100
Texas	North	Lambert	5326	-4201
	North Central	Lambert	5351	-4202
	Central	Lambert	5376	-4203
	South Central	Lambert	5401	-4204
	South	Lambert	5426	-4205
Utah	North	Lambert	5451	-4301
	Central	Lambert	5476	-4302
	South	Lambert	5501	-4303
Vermont	-------	Tr Merc	5526	-4400
Virginia	North	Lambert	5551	-4501
	South	Lambert	5576	-4502

Table 4. (concluded).

State	Zone Name	Type	Code Number USGS	Code Number NOS
Washington	North	Lambert	5601	-4601
	South	Lambert	5626	-4602
West Virginia	North	Lambert	5651	-4701
	South	Lambert	5676	-4702
Wisconsin	North	Lambert	5701	-4801
	Central	Lambert	5726	-4802
	South	Lambert	5751	-4803
Wyoming	East	Tr Merc	5776	-4901
	East Central	Tr Merc	5801	-4902
	West Central	Tr Merc	5826	-4903
	West	Tr Merc	5851	-4904
Puerto Rico and Virgin Islands		Lambert	6001	-5201
St. Croix	-------	Lambert	6051	-5202
Puerto Rico and Virgin Islands (Metric)		Lambert	6026	-5211
St. Croix (Metric)	-------	Lambert	6076	-5212

OPTION 3: ALBERS CONICAL EQUAL AREA

This secant conical projection produces very accurate area and distance measurements in the middle latitudes through use of two standard parallels (Fig. 5). Thus, Albers Conical Equal Area is well-suited to countries or continents where depth, north-south, is about 3/5 the breadth, east-west. Wnen this projection is used for the continental U.S., the two standard parallels are 29 1/2 degrees and 45 1/2 degrees North.

This projection possesses the property of equal area and the standard parallels are correct in scale and correct in every direction. Thus, there is no angular distortion (i.e., meridians intersect parallels at right angles) and conformality exists along the standard parallels. Like other conics, Albers Conical Equal Area has concentric arcs for parallels and equally spaced radii for meridians. Parallels are not equally spaced, but are farthest apart between the standard parallels, and closer together on north and south edges.

Albers Conical Equal Area is the projection exclusively used by the USGS for sectional maps of all 50 states of the U.S. in the National Atlas of 1970.

The ellipsoid menu and the following prompts will appear once option 3, Albers Conical Equal Area, is chosen from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

LATITUDE OF 1ST STANDARD PARALLEL ?

LATITUDE OF 2ND STANDARD PARALLEL ?

Enter two values for the desired control lines of the projection, i.e., the standard parallels. Note that the first standard parallel is the southernmost.

Then, define the origin of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTRAL MERIDIAN ?

LATITUDE ORIGIN OF PROJECTION ?

Enter values for longitude of the desired central meridian and latitude of the origin of projection.

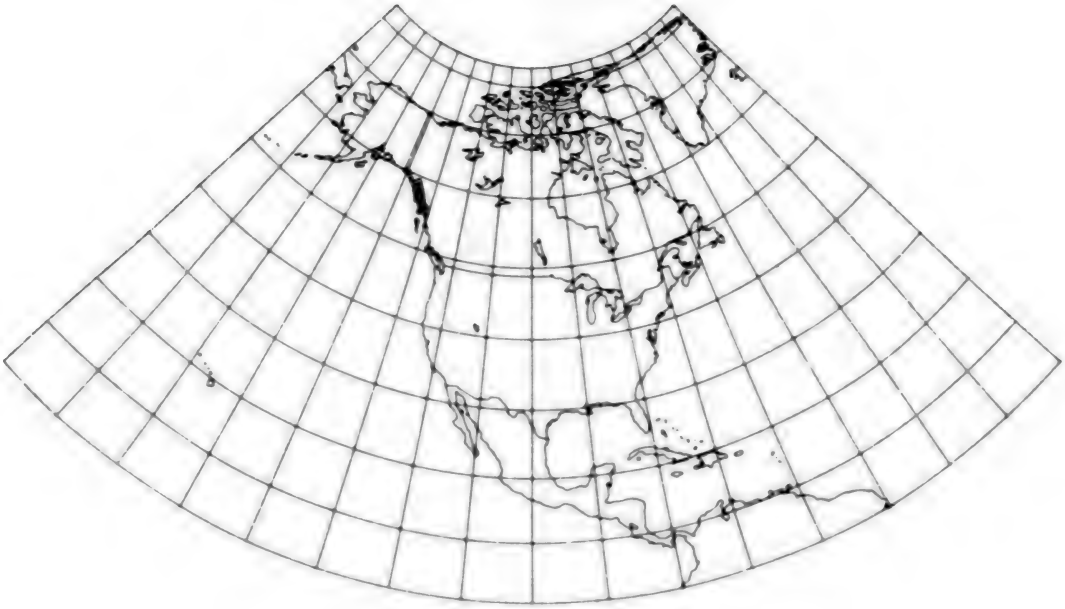


Figure 5. Albers Equal Area Conic projection. The standard parallels are 20 and 60 degrees North. Note the change in spacing of the parallels (from Snyder 1982).

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the intersection of the central meridian and the latitude of the origin of projection. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to make them large enough to prevent negative coordinates from occurring within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 4: LAMBERT CONFORMAL CONIC

This projection is very similar to Albers Conical Equal Area described previously. It too is a secant conical projection with two standard parallels (Fig. 6). This projection, like Albers, is most valuable in middle latitudes, especially in a country sprawling east to west like the U.S. The standard parallels for the U.S. are 33 degrees and 45 degrees North.

The major property of this projection is its conformality. At all coordinates, meridians and parallels cross at right angles. The correct angles produce correct shapes. Also, great circles are approximately straight. The conformal property of Lambert Conformal Conic and the straightness of great circles makes it valuable for landmark flying.

Lambert Conformal Conic is the State Plane coordinate system projection for states of predominant east-west expanse. Since 1962, Lambert Conformal Conic has been used for the International Map of the World between 84 degrees North and 80 degrees South.

In comparison with Albers Conical Equal Area, Lambert Conformal Conic possesses true shape of small areas whereas Albers possesses equal area. Unlike Albers, parallels of Lambert Conformal Conic are spaced at increasing intervals the farther north or south they are from the standard parallels.

The ellipsoid menu and the following prompts will appear if option 4, Lambert Conformal Conic, is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

LATITUDE OF 1ST STANDARD PARALLEL ?

LATITUDE OF 2ND STANDARD PARALLEL ?

Enter two values for the desired control lines of the projection, i.e. the standard parallels. Note that the first standard parallel is the southernmost.

Then, define the origin of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTRAL MERIDIAN ?

LATITUDE ORIGIN OF PROJECTION ?

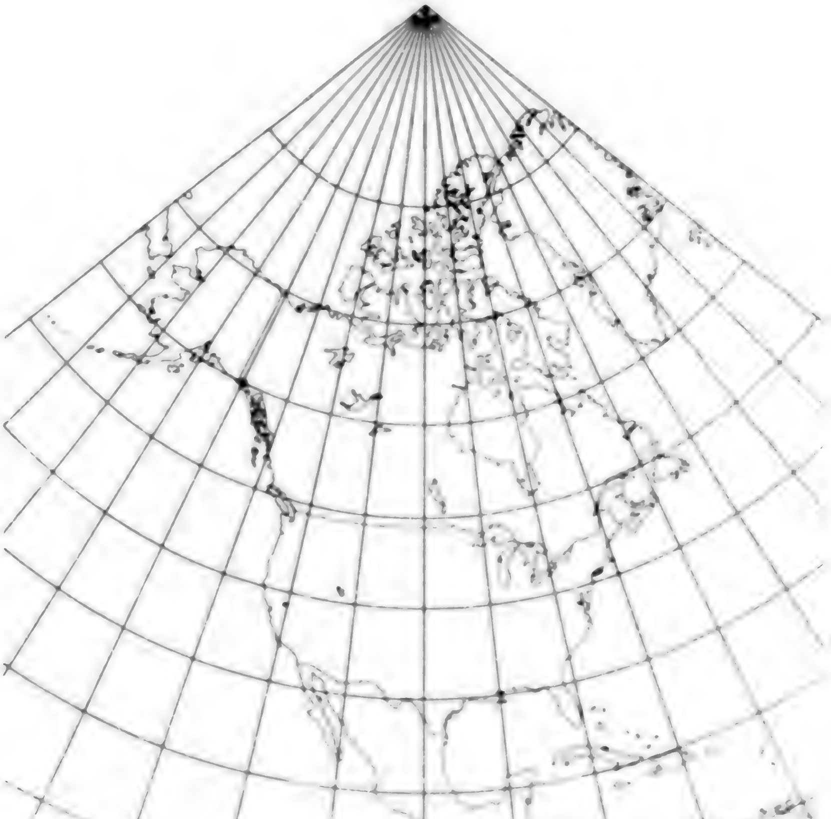


Figure 6. Lambert Conformal Conic projection. The standard parallels are 20 and 60 degrees North. Note the change in spacing of the parallels (from Snyder 1982).

Enter values for longitude of the desired central meridian and latitude of the origin of projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the intersection of the central meridian and the latitude of the origin of projection. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to make them large enough to ensure that there will be no negative coordinates within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 5: MERCATOR

This famous cylindrical projection was originally designed by Flemish map maker Gerhardus Mercator in 1569 to aid navigation (Fig. 7). Meridians and parallels are straight lines and cross at 90 degree angles. Angular relationships are preserved.

However, to preserve conformality, parallels are placed increasingly farther apart with increasing distance from the equator. Due to extreme scale distortion in high latitudes, the projection is rarely extended beyond 80 degrees North or South unless the latitude of true scale is other than the equator. Distance scales are usually furnished for several latitudes.

Rhumb lines, which show constant direction, are straight. For this reason a Mercator map was very valuable to sea navigators. However, rhumb lines are not the shortest path; great circles are the shortest path. Most great circles appear as long arcs when drawn on a Mercator map.

The ellipsoid menu and the following prompts will appear if option 5, Mercator, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

Define the origin of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTRAL MERIDIAN ?

LATITUDE OF TRUE SCALE ?

Enter values for longitude of the desired central meridian and latitude at which true scale is desired. Selection of a parameter other than the equator can be useful for making maps in extreme north or south latitudes.

ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

Enter values of false easting and false northing corresponding to the intersection of the central meridian and the latitude of true scale. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

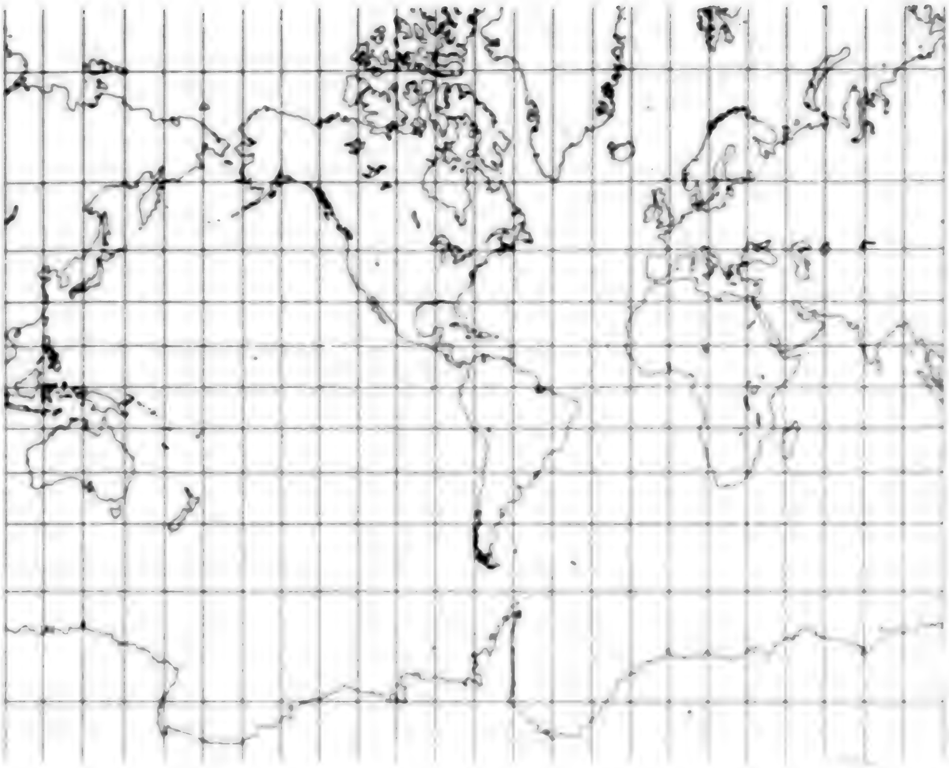


Figure 7. Mercator projection. All angles are shown correctly, therefore small shapes are true, i.e., it is conformal. Rhumb lines are straight which makes it useful in navigation (from Snyder 1982).

OPTION 6: POLAR STEREOGRAPHIC

Polar Stereographic is an azimuthal projection obtained by projecting from the opposite pole (Fig. 8). All of either the northern or southern hemispheres can be shown, but not both. This projection produces a circular map with one of the poles at the center.

Polar Stereographic stretches areas toward the periphery, and scale increases for areas farther from the central pole. Meridians are straight and radiating; parallels are concentric circles. Even though scale and area are not constant with Polar Stereographic, this projection, like all stereographic projections, possesses the property of conformality.

The ellipsoid menu and the following prompts will appear if option 6, Polar Stereographic, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

Define the origin of the map projection in both spherical and rectangular coordinates.

```
LONGITUDE DIRECTED STRAIGHT DOWN BELOW POLE ?
```

Enter a value for longitude directed straight down below the pole for a north polar aspect, or straight up from the pole for a south polar aspect. This is equivalent to centering the map with a desired meridian.

```
LATITUDE OF TRUE SCALE ?
```

Enter a value for latitude at which true scale is desired.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the pole. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to make them large enough to prevent negative coordinates within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

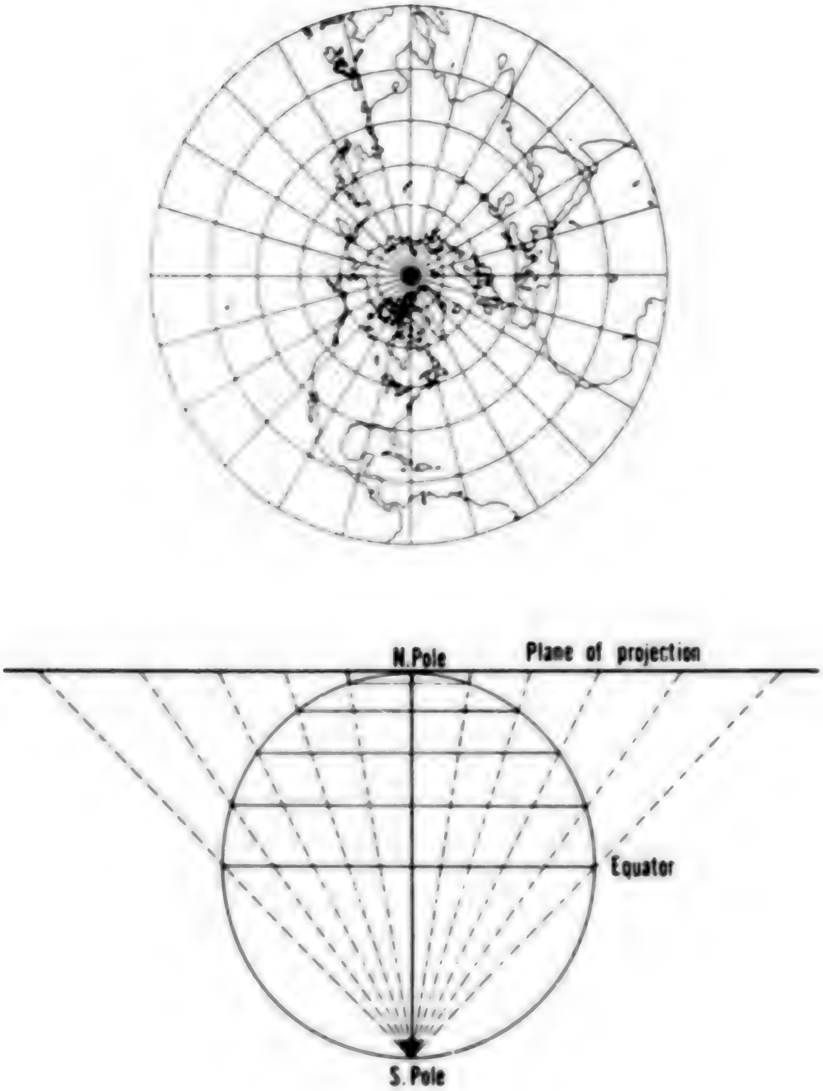


Figure 8. Polar Stereographic projection and its geometric construction. This projection is conformal and is the most common scientific projection for polar regions (from Snyder 1982).

OPTION 7: POLYCONIC

Polyconic was developed in 1820 by Ferdinand Hassler specifically for mapping the eastern coast of the U.S. (Fig. 9). Polyconic projections are made up of an infinite number of conic projections tangent to an infinite number of parallels. These conic projections are placed in relation to a central meridian.

This projection is used mostly for north-south oriented maps. Distortion increases greatly the farther east and west an area is from the central meridian.

Polyconic projections compromise properties such as equal area and conformality, although the central meridian is held true to scale. All parallels are arcs of circles, but not concentric. All meridians, excepting the central meridian, are concave toward the central meridian. Parallels cross the central meridian at equal intervals but get farther apart at the east and west peripheries.

The ellipsoid menu and following prompts will appear if option 7, Polyconic, is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

Define the origin of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTRAL MERIDIAN ?

LATITUDE ORIGIN OF PROJECTION ?

Enter values for longitude of the desired central meridian and latitude of the origin of projection.

ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

Enter values of false easting and false northing corresponding to the intersection of the central meridian and the latitude of the origin of projection. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

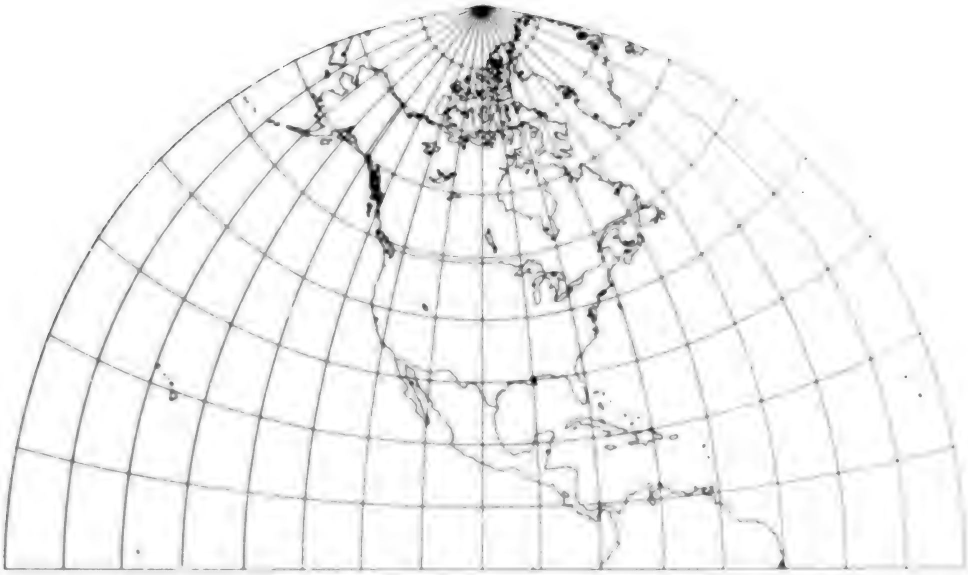


Figure 9. Polyconic projection of North America. The central meridian is 100 degrees West. This projection is used by the U.S. Geological Survey for topographic quadrangle maps (from Snyder 1982).

OPTION 8: EQUIDISTANT CONIC A & B

With Equidistant Conic projections, correct distance is achieved along the line(s) of contact with the cone, and parallels are equidistantly spaced. It can be used with either one (A) or two (B) standard parallels. This projection is neither conformal nor equal area, but the north-south scale along meridians is correct. Because scale distortion increases with increasing distance from the line(s) of contact, the Equidistant Conic is used mostly for mapping regions predominantly east-west in extent. The USGS uses the Equidistant Conic in an approximate form for a map of Alaska.

The ellipsoid menu and the following prompts will appear if option 8, Equidistant Conic A & B, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

```
1 EQUIDISTANCE CONIC TYPE A
2 EQUIDISTANCE CONIC TYPE B
```

Enter one or two for projection type A or B, respectively. Type B differs from type A because it is a secant projection with two standard parallels instead of a tangent projection with only one standard parallel.

```
LATITUDE OF 1ST STANDARD PARALLEL ?

LATITUDE OF 2ND STANDARD PARALLEL ?
```

Enter one or two (A or B type) value(s) for the desired control line(s) of the projection, i.e., the standard parallel(s). Note that if two standard parallels are used, the first is the southern-most.

Then, define the origin of the projection in both spherical and rectangular coordinates.

```
LONGITUDE OF CENTRAL MERIDIAN ?

LATITUDE ORIGIN OF PROJECTION ?
```

Enter values for the longitude of the desired central meridian and the latitude of the origin of projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the intersection of the central meridian and the latitude of the origin of projection. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 9: TRANSVERSE MERCATOR

Transverse Mercator is similar to the Mercator projection except that the axis of the projection cylinder is rotated 90 degrees from the vertical (polar) axis. The contact line is then a chosen meridian instead of the equator and this central meridian runs from pole to pole. It loses the properties of straight meridians and straight parallels of the standard Mercator projection (except for the central meridan, the two meridians 90 degrees away, and the equator).

Transverse Mercator also loses the straight rhumb lines of the Mercator map, but it is a conformal projection. Scale is true along the central meridian or along two straight lines equidistant from and parallel to the central meridian.

In the United States, Transverse Mercator is the projection used in the State Plane coordinate system for States with predominant north-south extent. The entire earth from 84 degrees North to 80 degrees South is mapped with a system of projections called the Universal Transverse Mercator (see option 1).

The ellipsoid menu and the following prompts will appear if option 9, Transverse Mercator, is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

SCALE FACTOR AT CENTRAL MERIDIAN ?

Designate the desired scale factor at the central meridian. This parameter is used to modify scale distortion. A value of one indicates true scale only along the central meridian. It may be desirable to have true scale along two lines equidistant from and parallel to the central meridian, or to lessen scale distortion away from the central meridian. A factor of less than, but close to, one is often used (see Snyder 1982).

Finally, define the origin of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTRAL MERIDIAN ?

LATITUDE ORIGIN OF PROJECTION ?

Enter values for longitude of the desired central meridian and latitude of the origin of projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the intersection of the central meridian and the latitude of the origin of projection. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to make them large enough so that there will be no negative coordinates within the region of the map projection. That is, origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 10: STEREOGRAPHIC

Stereographic is a perspective projection in which points are projected from a position on the opposite side of the globe onto a plane tangent to the earth (Fig. 10). All of one hemisphere can easily be shown, but it is impossible to show both hemispheres in their entirety from one center. It is the only azimuthal projection that preserves truth of angles and local shape. Scale increases and parallels become more widely spaced farther from the center.

In the equatorial aspect, all parallels except the equator are circular arcs. In the polar aspect, latitude rings are spaced farther apart with increasing distance from the pole.

The ellipsoid menu and the following prompts will appear if option 10, Stereographic, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

Define the center of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTER PROJECTION ?

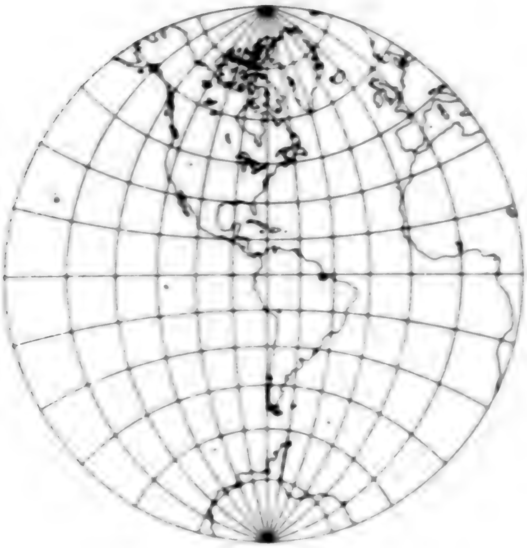
LATITUDE OF CENTER OF PROJECTION ?

Enter values for the longitude and latitude of the desired center of the projection.

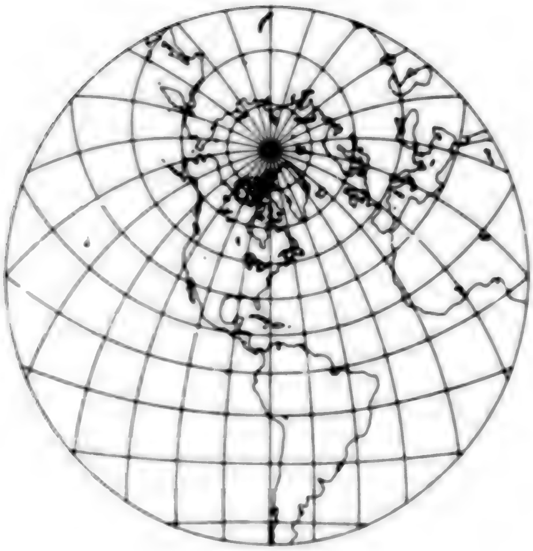
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

Enter values of false easting and false northing corresponding to the center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.



a)



b)

Figure 10. Stereographic projection. This is the only azimuthal projection which is conformal. a) equatorial aspect; often used in the 16th and 17th centuries for maps of hemispheres. b) oblique aspect; centered on 40 degrees North (from Snyder 1982).

OPTION 11: LAMBERT AZIMUTHAL EQUAL AREA

Lambert Azimuthal Equal Area has the property of equal area, as its name implies (Fig. 11). It also provides a complete round of true direction from the central point (centrally true azimuths). This point can be located anywhere. Concentric circles are closer together as you move to the edge of the map and the scale distorts accordingly. This projection is well suited to square or round land masses.

In the polar aspect, latitude rings decrease their intervals from the center outwards. In the equatorial aspect, parallels are curves flattened in the middle. Meridians are also curved, except for the central meridian, and spacing decreases as you approach the edges.

The ellipsoid menu and the following prompts will appear if option 11, Lambert Azimuthal Equal Area, is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

Define the center of the map projection in both spherical and rectangular coordinates.

```
LONGITUDE OF CENTER PROJECTION ?

LATITUDE OF CENTER OF PROJECTION ?
```

Enter values for the longitude and latitude of the desired center of the projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough to prevent negative coordinates within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

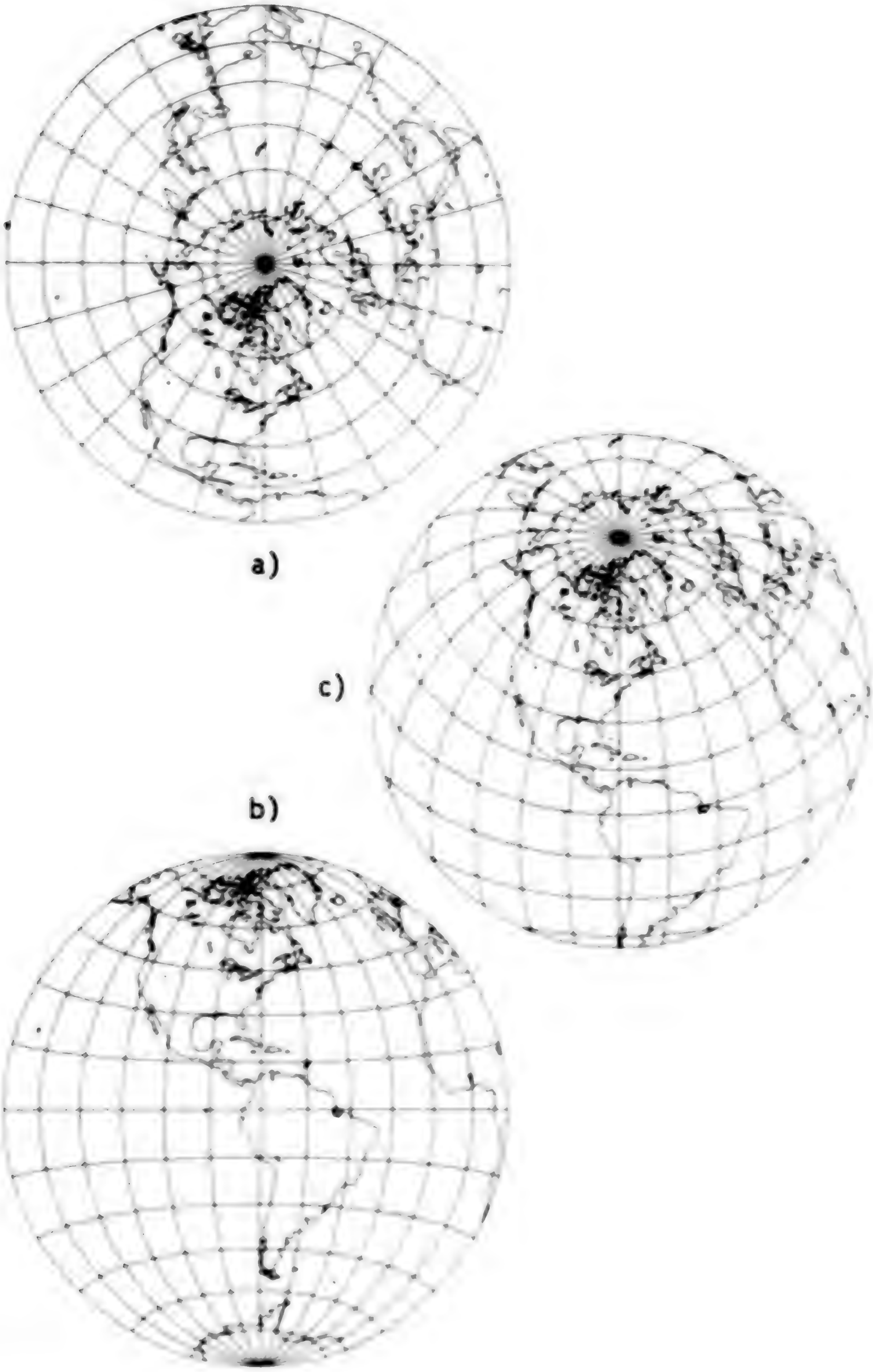


Figure 11. Lambert Azimuthal Equal Area projection. a) polar aspect; showing one hemisphere. b) equatorial aspect; frequently used in old atlases for maps of the eastern and western hemispheres. c) oblique aspect; centered on 40 degrees North (from Snyder 1982).

OPTION 12: AZIMUTHAL EQUIDISTANT

Azimuthal Equidistant is used mostly for polar projections because latitude rings divide meridians at equal intervals with a polar aspect (Fig. 12). Linear scale distortion is moderate and increases towards the periphery. Meridians are equally spaced, and all distances and directions are shown accurately from the central point.

This projection can also be used to center on any point on the earth, a city, for example, and distance measurements will be true from that central point. Distances are not correct or true along parallels, and the projection is neither equal area nor conformal. Also, straight lines radiating from the center of this projection represent great circles.

The ellipsoid menu and the following prompts will appear if option 12, Azimuthal Equidistant, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

Define the center of the map projection in both spherical and rectangular coordinates.

```
LONGITUDE OF CENTER PROJECTION ?

LATITUDE OF CENTER OF PROJECTION ?
```

Enter values for the longitude and latitude of the desired center of the projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

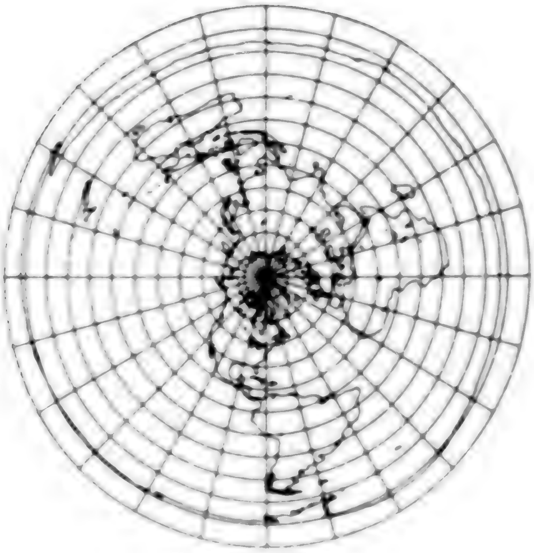


Figure 12. Polar aspect of the Azimuthal Equidistant projection. This projection is commonly used in atlases for polar maps (from Snyder 1982)

OPTION 13: GNOMONIC

Gnomonic is a perspective projection that projects onto a tangent plane from a position in the center of the earth. Because of the close perspective, this projection is limited to less than a hemisphere. However, it is the only projection which shows all great circles as straight lines.

With a polar aspect, the latitude intervals increase rapidly from the center outwards. With an equatorial or oblique aspect, the equator is straight. Meridians are straight and parallel, while intervals between parallels increase rapidly from the center and parallels are convex to the equator.

Because great circles are straight, this projection is useful for air and sea navigation. Rhumb lines are curved, which is opposite of the Mercator.

The ellipsoid menu and the following prompts will appear if option 13, Gnomonic, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

Define the center of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTER PROJECTION ?

LATITUDE OF CENTER OF PROJECTION ?

Enter values for the longitude and latitude of the desired center of the projection.

ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

Enter values of false easting and false northing corresponding to the center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough to prevent negative coordinates within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 14: ORTHOGRAPHIC

Orthographic is a perspective projection obtained by looking back on the earth from a practical infinity, for example, from Mars (Fig. 13). Light rays that cast the projection are parallel and intersect the tangent plane at right angles.

This projection is limited to one hemisphere and shrinks those areas towards the periphery. In the polar aspect, latitude ring intervals decrease from the center outwards at a much greater rate than with Lambert Azimuthal. In the equatorial aspect, the central meridian and parallels are straight, with spaces closing up toward the outer edge.

Scale is true on parallels in the polar aspect and on all circles centered at the pole of the projection in all aspects. Scale decreases along lines radiating from the center of the projection.

The Orthographic projection seldom appears in atlases. Its utility is more pictorial than technical. Orthographic has been used as a basis for artistic maps by Rand McNally and the USGS.

The ellipsoid menu and the following prompts will appear if option 14, Orthographic, is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

Define the center of the map projection in both spherical and rectangular coordinates.

LONGITUDE OF CENTER PROJECTION ?

LATITUDE OF CENTER OF PROJECTION ?

Enter values for the longitude and latitude of the desired center of the projection.

ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

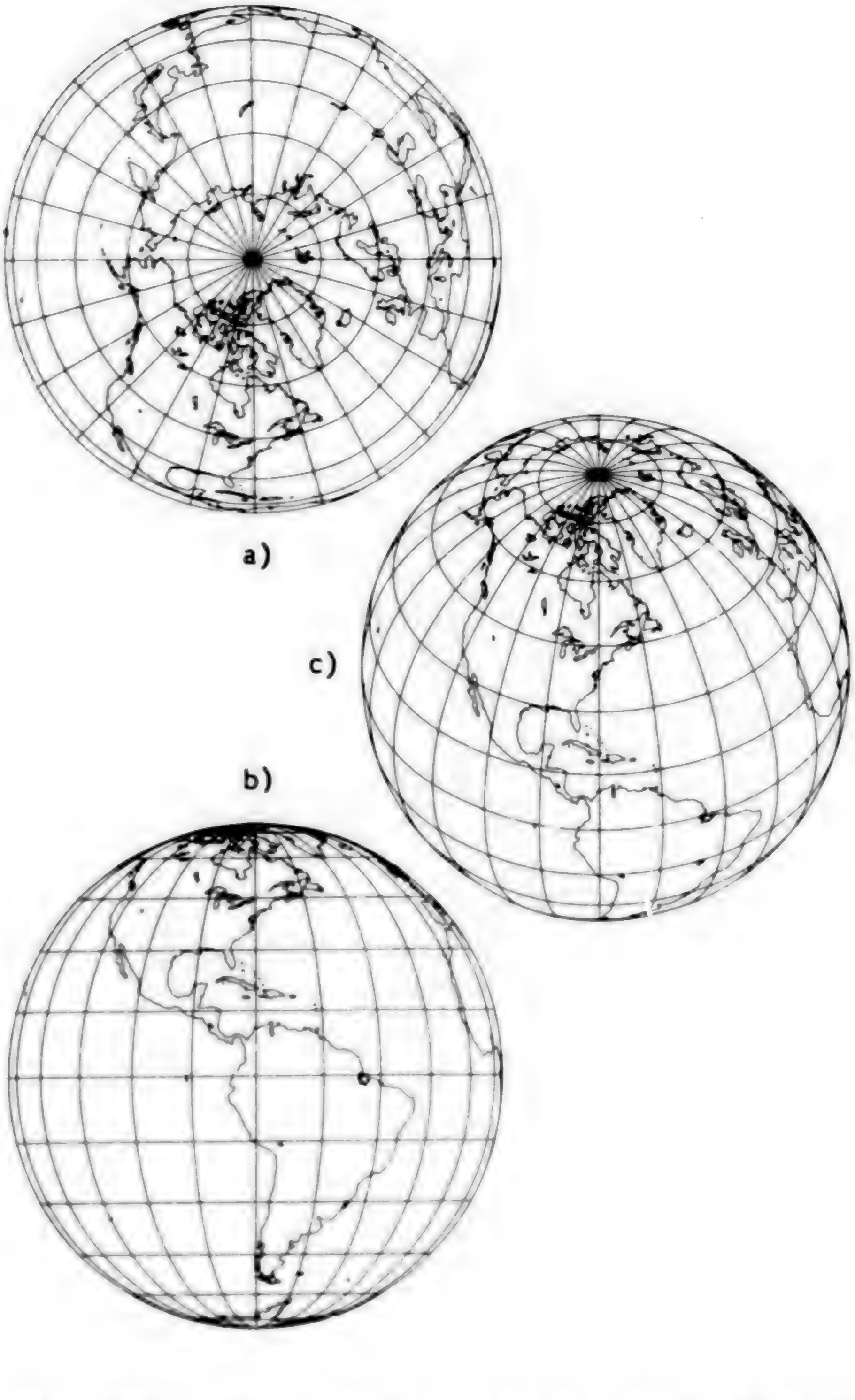


Figure 13. Orthographic projection. a) polar aspect. b) equatorial aspect. c) oblique aspect; centered at 40 degrees North and showing the classic globe-like view (from Snyder 1982).

Enter values of false easting and false northing corresponding to the center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 15: VERTICAL NEAR SIDE PERSPECTIVE

Vertical Near Side Perspective presents a picture of the earth as if a photograph were taken at some distance less than infinity. The map user simply identifies area of coverage, distance of view, and angle of view.

Like all perspective projections, Vertical Near Side Perspective cannot illustrate the entire globe on one map; it can only represent part of one hemisphere.

The ellipsoid menu and the following prompts will appear if option 15, Vertical Near Side Perspective, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

```
HEIGHT OF PERSPECTIVE POINT ABOVE SPHERE ?
```

Enter a value for desired height of the perspective point above the sphere in the same units as the radius.

Then, define the center of the map projection in both spherical and rectangular coordinates.

```
LONGITUDE OF CENTER PROJECTION ?

LATITUDE OF CENTER OF PROJECTION ?
```

Enter values for the longitude and latitude of the desired center of the projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 16: SINUSOIDAL

Sometimes called the Sanson-Flamsteed, Sinusoidal is a projection with some characteristics of a cylindrical projection; often called a pseudocylindrical type. The central meridian is the only straight meridian; all others become sinusoidal curves. All parallels are straight, and the correct length. Parallels are also the correct distance from the equator, which, for a complete world map, is twice as long as the central meridian.

Sinusoidal maps achieve the property of equal area but not conformality. The equator and central meridian are distortion free, but distortion becomes pronounced near outer meridians, especially in polar regions.

Interrupting a Sinusoidal world or hemisphere map can lessen distortion. The interrupted Sinusoidal contains less distortion because each interrupted area can be constructed to contain a separate central meridian. Central meridians may be different for the northern and southern hemispheres and may be selected to minimize distortion of continents or oceans.

Sinusoidal is particularly suited for less than world areas, especially those bordering the equator, such as South America or Africa. Sinusoidal is also used by the USGS as a base map for showing prospective hydrocarbon provinces and sedimentary basins of the world.

The ellipsoid menu and the following prompts will appear if option 16, Sinusoidal, is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

LONGITUDE OF CENTRAL MERIDIAN ?

Enter a value for the longitude of the desired central meridian to center the projection.

ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

Enter values of false easting and false northing corresponding to the desired center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough to prevent negative coordinates within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 17: EQUIRECTANGULAR (PLATE CARREE)

Also called Simple Cylindrical, Equirectangular is composed of equally spaced parallel meridians and latitude lines which cross at right angles on a rectangular map. Each rectangle formed by the grid is equal in area, shape, and size. Equirectangular is not conformal nor equal area, but it does contain less distortion than the Mercator in polar regions. Scale is true on all meridians and on the central parallel. Directions due north, south, east, and west are true, but all other directions are distorted.

In Plate Carree form the equator is the standard parallel, true to scale and free of distortion. However, this projection may be centered anywhere.

This projection is valuable for its ease in computer plotting. It is useful for mapping small areas such as city maps because of its simplicity. The USGS uses Equirectangular for index maps of the conterminous U.S. with insets of Alaska, Hawaii, and various islands. However, neither scale nor projection is marked to avoid implying that the maps are suitable for normal geographic information.

The ellipsoid menu and the following prompts will appear if option 17, Equirectangular, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

LONGITUDE OF CENTRAL MERIDIAN ?

Enter a value for longitude of the desired central meridian to center the projection.

ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

Enter values of false easting and false northing corresponding to the desired center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

OPTION 18: MILLER CYLINDRICAL

Miller Cylindrical is a modification of the Mercator projection (Fig. 14). It is similar to the Mercator from the equator to 45 degrees, but Miller modified latitude line intervals so that the distance between them increases less rapidly. Thus, beyond 45 degrees, Miller Cylindrical lessens the extreme exaggeration of the Mercator. Miller Cylindrical also includes the poles as straight lines whereas the Mercator does not.

Meridians and parallels are straight lines intersecting at right angles. Meridians are equidistant, while parallels are spaced farther apart the farther they are from the equator. Miller Cylindrical is not equal-area, equidistant, nor conformal. Miller Cylindrical is used for world maps and in several atlases.

The ellipsoid menu and the following prompts will appear if option 18, Miller Cylindrical, is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

```
LONGITUDE OF CENTRAL MERIDIAN ?
```

Enter a value for the longitude of the desired central meridian to center the projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the desired center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough to prevent negative coordinates within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

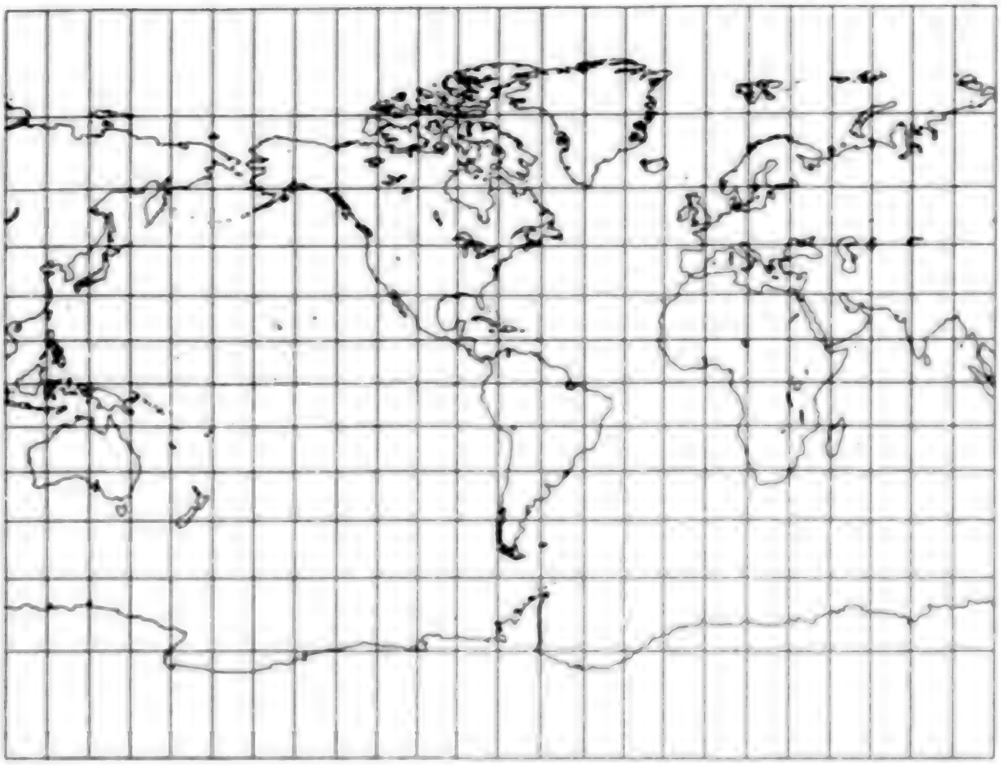


Figure 14. Miller Cylindrical projection. This projection resembles the Mercator but has less distortion in polar regions. Miller Cylindrical is neither conformal nor equal area (from Snyder 1982).

OPTION 19: VAN DER GRINTEN I

A Van der Grinten projection produces a map that is neither conformal nor equal area (Fig. 15). It compromises all properties, and presents a rather pleasing picture of the world as a whole. It is a round map which represents the earth within a circle.

All lines are curved except the central meridian and the equator. Parallels are spaced farther apart towards the poles. Meridian spacing is equal at the equator. Scale is true along the equator but increases rapidly towards the poles, which are usually not represented.

Van der Grinten avoids the excessive stretching of the Mercator and the shape distortion of many of the equal area projections. It has been used to show distribution of mineral resources on the ocean floor.

The ellipsoid menu and the following prompts will appear if option 19, Van der Grinten I, is selected from the map projection menu. Choose an ellipsoid and then respond to the prompts as described.

```
LONGITUDE OF CENTRAL MERIDIAN ?
```

Enter a value for the longitude of the desired central meridian to center the projection.

```
ENTER FALSE EASTING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID

ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

Enter values of false easting and false northing corresponding to the center of the projection. These values must be in the same units of measure as the radius of the reference sphere (meters or feet). It is very often convenient to make them large enough to prevent negative coordinates within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

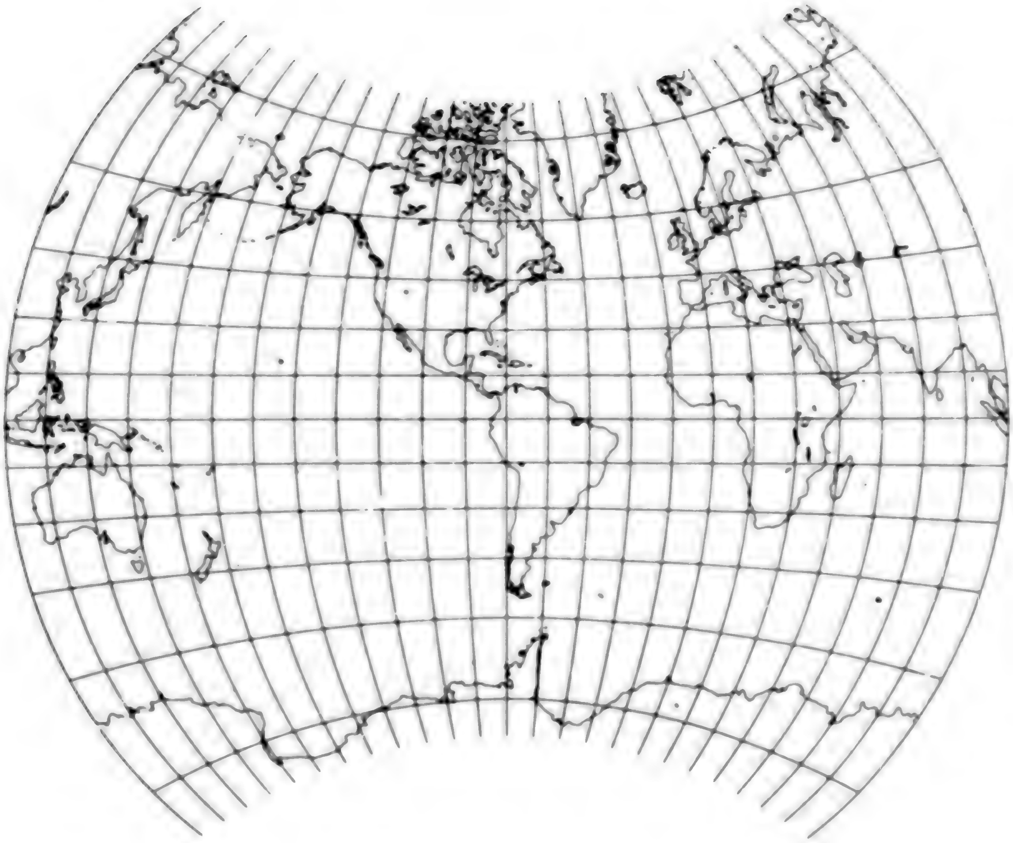


Figure 15. Van der Grinten projection. This projection resembles the Mercator but is not conformal (from Snyder 1982).

OPTION 20: OBLIQUE MERCATOR (HOTINE) A & B

Oblique Mercator is a cylindrical, conformal projection that intersects the global surface along a great circle. It is equivalent to a Mercator projection which has been altered by rotating the cylinder so that the central line of the projection is a great circle path instead of the equator.

The USGS uses the Hotine version of Oblique Mercator. The Hotine version is based on a study of conformal projections published by British geodesist Martin Hotine in 1946-47. Prior to the implementation of the Space Oblique Mercator, the Hotine version was used for mapping Landsat satellite imagery.

The ellipsoid menu and the following prompts will appear if option 20, Oblique Mercator (Hotine), is selected from the map projection menu. Select an ellipsoid and then respond to the prompts as described.

```
1 OBLIQUE MERCATOR (FORMAT A)
2 OBLIQUE MERCATOR (FORMAT B)
```

Enter one or two for format type A or B, respectively. These formats differ slightly in definition of the central line of the projection (see below, and for more detail, Snyder 1982).

```
SCALE FACTOR AT CENTER OF THE PROJECTION ?
```

Designate the desired scale factor along the central line of the projection. This parameter may be used to modify scale distortion away from this central line. A value of 1.0 indicates true scale only along the central line. A value of less than, but close to, one is often used to lessen scale distortion away from the central line (see Snyder 1982).

At this point the prompts for format A diverge from those for format B.

For format A the additional prompts are:

```
LATITUDE ORIGIN OF PROJECTION ?

LONGITUDE OF 1ST POINT DEFINING CENTRAL GEODETIC LINE ?

LATITUDE OF 1ST POINT DEFINING CENTRAL GEODETIC LINE ?

LONGITUDE OF 2ND POINT DEFINING CENTRAL GEODETIC LINE ?

LATITUDE OF 2ND POINT DEFINING CENTRAL GEODETIC LINE ?
```

Format A defines the central line of the projection by the latitude of a point on the central line which has the desired scale factor entered previously and by the longitude and latitude of two points along the desired great circle path. Appropriate values should be entered.

For format B the additional prompts are:

```
     ANGLE OF AZIMUTH EAST OF NORTH FOR CENTRAL
     LINE OF PROJECTION ?

     LATITUDE ORIGIN OF PROJECTION ?

     LONGITUDE OF POINT ALONG CENTRAL LINE OF
     PROJECTION WHERE ANGLE OF AZIMUTH IS MEASURED ?
```

Format B defines the central line of the projection by the angle east of north to the desired great circle path and by the latitude and longitude of the point along the great circle path from which the angle is measured. Appropriate values should be entered.

```
     ENTER FALSE EASTING IN SAME UNITS OF MEASURE
     AS THE SEMI-MAJOR AXIS OF ELLIPSOID

     ENTER FALSE NORTHING IN SAME UNITS OF MEASURE
     AS THE SEMI-MAJOR AXIS OF ELLIPSOID
```

The center of the projection is defined by rectangular coordinates of false easting and false northing. The origin of rectangular coordinates on this projection occurs at the nearest intersection of the central line with the earth's equator. To shift the origin to the intersection of the latitude of the origin entered above and the central line of the projection, compute coordinates of the latter point with zero false eastings and northings, reverse the signs of the coordinates obtained, and use these for false eastings and northings. These values must be in the same units of measure as the axes of the ellipsoid (meters or feet). It is very often convenient to add additional values so that no negative coordinates will occur within the region of the map projection. That is, the origin of the rectangular coordinate system should fall outside of the map projection to the south and west.

GLOSSARY

aspect - Orientation of the projection surface.

azimuth - A line of true direction.

azimuthal projection - A projection onto a tangent plane from any central point.

compromise projection - Rather than preserving one map property and distorting all others, this projection distorts all properties to a lesser degree.

conformal - A transformation of the earth's geometry preserving small shapes. Shape preservation is maintained when all angles on the earth's surface are transformed into equal angles on the map.

conical projection - Projection onto a cone, tangent or secant to the globe.

cylindrical projection - Projection onto a cylinder, tangent or secant to the globe.

developable surface - A curved surface which may be imagined flattened out without distorting any element, e.g., a cone or cylinder.

equal area - A projection for which area on a map maintains a constant scale across the entire map.

equatorial aspect - The projection surface is centered at any point along the equator.

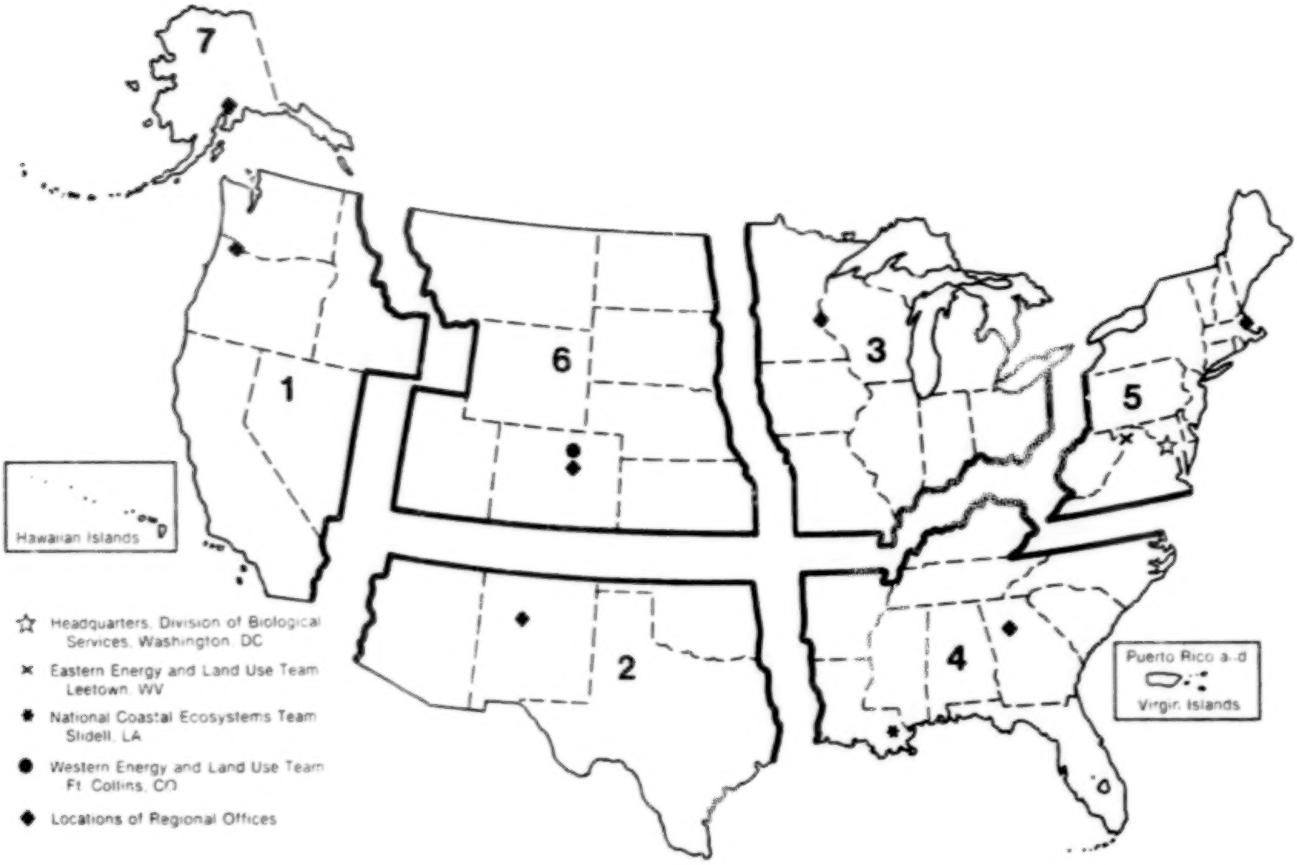
equidistant - A map that presents distances in constant scale from an identified point.

equivalence - Synonymous with equal area. See above.

gnomonic - An azimuthal projection obtained from a perspective at the center of the earth.

graticule - The network of parallels of latitude and meridians of longitude applied to the global surface and projected onto maps.

great circle - The shortest possible surface route between two points on the earth.


7
1
6
3
5
2
4
Hawaiian Islands
Puerto Rico and Virgin Islands
☆ Headquarters, Division of Biological Services, Washington, DC
× Eastern Energy and Land Use Team Leetown, WV
✱ National Coastal Ecosystems Team Slidell, LA
● Western Energy and Land Use Team Ft. Collins, CO
◆ Locations of Regional Offices

REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

END

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